Ueber die von v. Kries wider die Theorie der Gegenfarben erhobenen Einwände. E. HERING. Pflüger's Archiv, XLII, u. XLIII.

I. Following out the mathematical discussion of the conditions of color-mixtures which he gave in his *Newton's Gesetz der Farben-Mischung*, Hering replies in detail to v. Kries' objection that when more than three fundamental colors are assumed color-mixtures which look alike at one degree of fatigue do not necessarily look alike at a different degree of fatigue. The objection of v. Kries is based upon the assumption that the three distinguishable qualities of a given color-mixture (tone, intensity and saturation) give rise to three equations expressing respectively the identity of the same function of three processes when the processes are modified by different fatigue co-efficients. Three equations involving *three* unknown quantities (the fundamental processes) suffice to determine those unknown quantities but not if they involve more than three.

To this Hering very properly replies (overlooking the arbitrariness of the original assumption) that it is not necessary that the colors should *necessarily* look alike, but that it is sufficient that one of the many possible solutions of the equations should *permit* them to look alike, provided that that is not a solution that is otherwise improbable. Hering goes through a complete discussion of the question in the case of the reduction of the plane of color-mixtures to a straight line,—that is, in the case of the partially color-blind. The discussion involves modern mathematical methods, which, as Hering has shown in the case of the horopter, are eminently applicable here also.

II. Hering lays great stress upon the fact that the nervous visual organ is an organic whole, and that when a stimulus falls upon a part of the retina, all the other parts, and especially those which are near, respond as well. This is the key-note of Hering's explanation of the phenomena of induced self-color. These phenomena are, according to Hering, of the utmost importance from a theoretical point of view; the value of v. Kries' contributions to the subject may be inferred from the fact that he says (*Analyse d. Gesichtsempfindungen*, p. 133), that they have not nor *can* not contribute anything towards a theory of vision.

Hering repeats with various modifications, his fundamental experiments for exhibiting the *Licht-hof*, or bright border by which the dark after-image of a bit of white paper on black is surrounded. On Helmholtz' theory, this brightness is merely the ordinary self-light of the retina, heightened by judgment contrast with the dark after-image. Hering gives many ingenious experiments to prove that this is not the case, and in particular he provides that the "border" should be produced in one eye only while the other eye, having been shut (and hence rested), looks upon an actual grey surface with which to compare it. Anyone who has performed this experiment can no longer doubt that the "border" corresponds to a real sensation, of quite comparable intensity with that of a good grey light falling upon an untired retina; there is no reason to suppose that it is not due to a physiological process, of whatever nature it may be, superinduced by the adjoining stimulation. In the same way the after-image of a black strip on a red ground may look a brighter red than an actual red with which an unfatigued eye compares it. Von Kries says that this can be explained as a propagation of the *stimulation* instead of the excitability. Hering in reply points out that (in the form of experiment in which a narrow black strip with a sheet of white on either side of it looks afterwards bright) the strip grows dark as the sheets are brought up and bright again as they are again removed, but that if the sheets diffuse a stimulation they ought to do it the more the nearer they are to the black strip. This reply is perfectly adequate, but to the reviewer it is impossible to see why it does not hold against Hering's theory as well.

What difference is there between an increased excitability and an increased excitation, of such a nature that one can be diffused when the sheet is not there and the other only when the sheet is there?

Von Kries says that this border is only seen on a dark back-ground, but that if it were caused by an increased excitability that ought to betray itself on a bright back-ground as well, whereas a real process might easily be so slight as not to be noticed in the presence of a greater one. Hering shows that, with a proper arrangement, it can be seen on a bright back-ground; but he does not explain why it ought not always to be easily noticeable on a bright back-ground. Hering points out that he has not proposed any theory as to what the physiological process is which is the basis of the increased excitability, but that he is only engaged at present in getting a correct mode of expression for the facts. A third position which v. Kries takes up is that everything can be explained as well by assuming that an excitation in one spot lowers, instead of heightens, the surrounding excitability, but Hering shows that this is quite incompatible with several variations of the experiment to which v. Kries has not applied it. [It must be remembered that *excitation*, according to Hering's complete theory, must correspond now to a state of super-nutrition and now to a state of mal-nutrition in the nervous structures; the co-color sensations, red-green and blue-yellow, are, according to him, processes of assimilation and dissimilation respectively. Hence Hering must say, in full, that a tearing down of nervous structures in one spot causes a *tendency* to tearing down in surrounding spots. But what can a tendency to tearing down consist in, if it does not consist in a greater built-up-ness of some chemical structure? A chemical substance which is the same as to quality and amount cannot be now more and now less loosely put together. Hering's theory would therefore seem to be *at bottom* the same thing as this suggestion which is casually thrown out by v. Kries. In fact, the reasonableness of Hering's theory of vision, as far as it involves assimilation and dissimilation is a very different matter from its reasonableness exclusive of those ideas. The whole subject is in a condition in which it will repay any amount of hard thinking and careful experimenting.]

III. The third division of Hering's paper deals with after-images. Von Kries overlooks the fact that according to Hering's theory, fatigue for one color can exist without producing any change in the sensibility to white; while according to Helmholtz, fatigue for one color involves a total change in the reactions to white light. Take a yellow which is produced, on Helmholtz' theory, by equal excitations of the fibres sensible to green and to red. Let white light presently fall upon the same spot of the retina, and the green and red fibres being equally fatigued, it ought to stir up the violet fibres only; but in fact the complementary color to yellow is blue, or, at most, an indigo-blue. [Helmholtz, it would seem, would need to add to his theory the assumption that the green fibres are exceedingly vigorous, and not easily capable of fatigue; but, in fact, it is as easy to get the complementary color to green as to anything else.] Hering proceeds to describe a very striking experiment; a piece of spectral red is looked at first, fixedly in a bright light, and then the light is diminished, (or the observer takes the red paper into a shaded place.) Instantly, although his eyes are open and he is looking at red paper in a not faint light, it looks to him of a bright blue-green. A modification of this experiment is to place three bits of paper (red, green and violet) on black, to look at a point midway between them for a moment, and then to turn down the light. Each bit of paper appears in its complementary color, and as all the colors are present, a mistaken judgment cannot be called upon for an explanation of the phenomenon. Simple fatigue cannot explain

it, for if the fatigue of the red fibres is so great that a real red looks blue-green, why does it not betray itself before the shadowing? If the shadow be removed, the red looks as bright as before.

We are forced to assume that exposure to red light causes a strong disposition to the production of a blue-green sensation, not simply an indisposition to the production of a red sensation. At this point Hering commits a curious error in logic. He thinks that the objection set forth above to the possibility of two complementary colors both containing any considerable amount of green is *more* forcible on the supposition that an image and its after-image correspond to positive and negative forms of one process (viz. growth and decay) than that they correspond to different *degrees* of a positive or a negative process merely. He forgets that the difference between two quantities, both positive or both negative, may easily be as great as that between a positive quantity and a negative quantity. His reviewer, Schön, in *Hermann u. Schwalbe's Jahresberichte über die Fortschritte der Anat. u. Physiol.* gravely sets forth this position of Hering's without comment. The objection is a perfectly valid objection to a three-color theory as opposed to a four-color theory, but it has nothing whatever to say to a theory of assimilation plus dissimilation as opposed to a theory which attributes complementary sensations to the breaking down of two different kinds of chemical substance.

On the whole, this paper of Hering's which contains a large number of ingenious experiments, for the most part carefully weighed, does much to strengthen the belief that the black-white sensation is distinct from the color-sensation, and not composed of its combinations, but very little to strengthen the belief that the sensations of black and white (and of the opposite colors) are the psychological aspect of anabolic and metabolic processes respectively.

The principal weakness at present which exhibits itself on Hering's side of the question is that in his late papers he confines himself to answering objections, and does not sufficiently indicate, at each step, in what way his own theory applies to the case in question. He has promised a full discussion of the subject *de novo*, but that discussion seems to be long in coming. C. L. F.

Ueber den Farbensinn bei indirectem Sehen. Dr. CARL HESS. v. Graefe's Archiv für Ophthalmologie, Bd. XXXV, H. 4, 1889.

This very important paper is a thorough re-examination of the color sensibility of the peripheral portions of the retina. The general results are as follows: (1). Three kinds of homogeneous light can be found, and only three, which change in saturation, but not in color tone, as they are moved toward the periphery of the retina, the eye of course being wholly free from the effects of other color sensations previous or simultaneous. These are a yellow (wave length, 576–574 $\mu\mu$), a green (wave length 497–494 $\mu\mu$), and a blue (wave length 472–470 $\mu\mu$.) The same is also true of a fixed compound color mixed from homogeneous red and homogeneous violet or blue, except where the absorption of the *macula lutea* interferes. (The effect of the *macula* must be regarded in almost all these experiments so far as they are made with mixed colors.) These four unchanged colors are the primary colors (*Urfarben*) of Hering, determined in a purely objective manner. (2) Mixed lights agreeing with these in color-tone, and only such, behave as these do. (3). These four colors, homogeneous or mixed, form two complementary pairs *i. e.*, the mixture of the red and the green and of the yellow and the blue gives white. (4) Reds and greens that differ from the primary red and green become more and more yellow or more and more blue as they advance toward the periphery, finally losing all red and green character and appearing a more or less sat-